

# Oregon DOT Geometronics Unit Update

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Lead Geodetic Surveyor  
ODOT Geometronics Unit  
16 September 2008  
CGSIC States & Localities  
Savannah, Georgia

# Mission: ODOT Geometronics Unit

- ◆ Preserve and enhance geodetic control in the State of Oregon

# Overview

- ◆ Gravity Campaign in Oregon
  - NGS National Gravity Survey Plan
  - Oregon Gravity Surveys 2007
- ◆ Precise Digital Leveling in Oregon
- ◆ Oregon Real-time GPS Network Update
- ◆ Outreach/Education

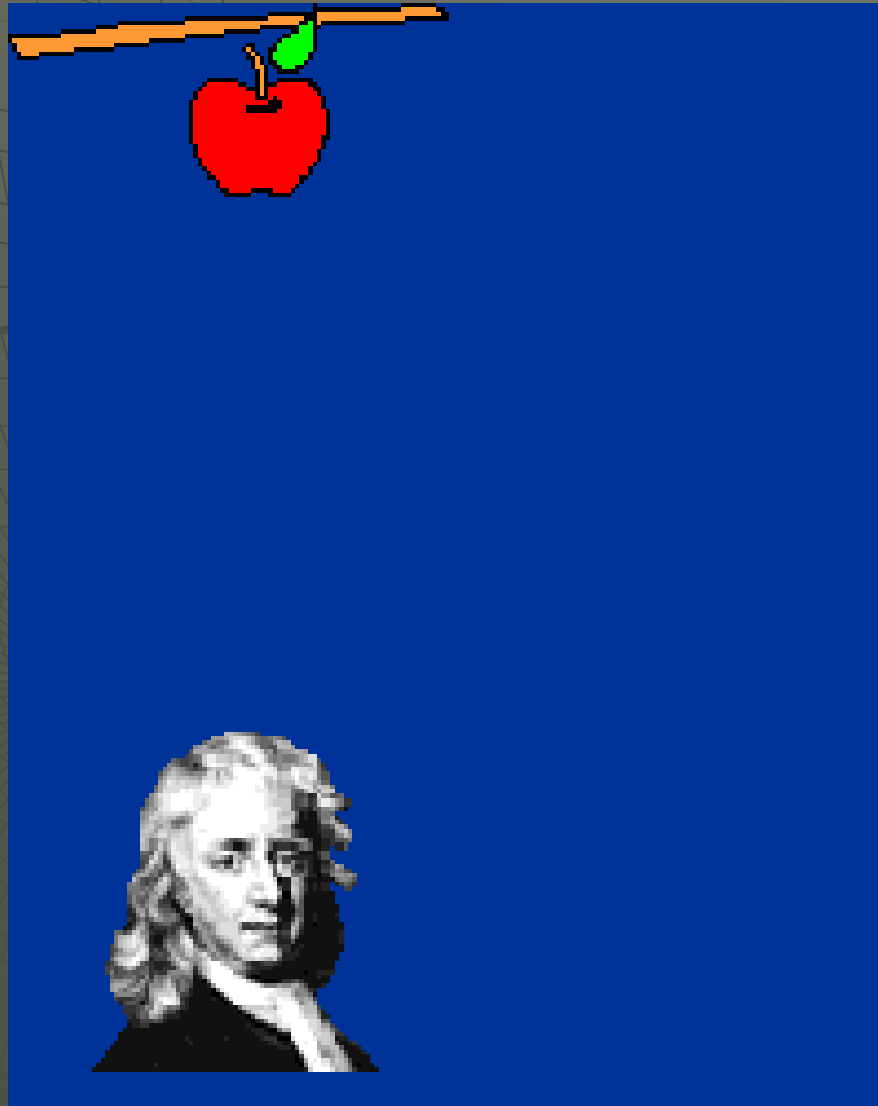
# Gravity

- ◆ NGS National Gravity Survey Plan
- ◆ 2007 Oregon Gravity Survey





# Sir Isaac Newton (1643-1727)



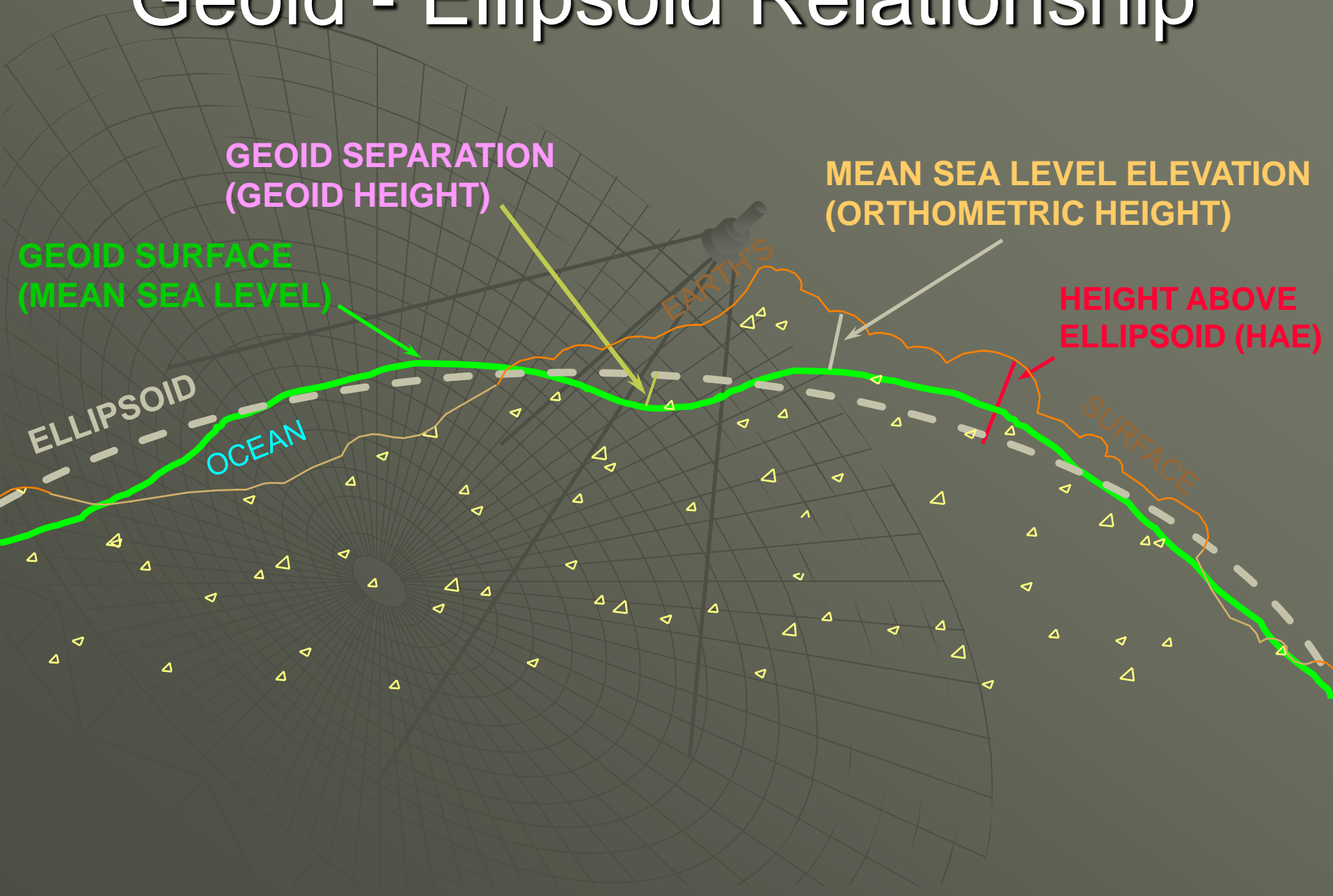
# NGS National Gravity Survey Plan

- ◆ The GRAV-D Project:
  - Gravity for the Redefinition of the American Vertical Datum
- ◆ “Accurate gravity data is the foundation for the Federal government’s determination of heights”

# Why a Gravity Survey is Needed

- ◆ “GPS Ellipsoid heights cannot be used to determine where water will flow, and therefore are *not* used in topographic/floodplain mapping.”
- ◆ “Orthometric heights are related to water flow and more useful.”
  - **NGS National Gravity Survey Plan**

# Geoid - Ellipsoid Relationship





# Why a Gravity Survey is Needed

- ◆ “In order to transform from ellipsoid heights to orthometric heights, a model of *the geoid* must be computed.”
- ◆ “Geoid modeling *can only be done with measurements of the acceleration of gravity near the Earth’s surface.*”
  - **NGS National Gravity Survey Plan**

# Grav-D Project Summary

- ◆ I. High resolution snapshot
  - to repair and improve existing gravity holdings
  - a one-time survey with dense spatial coverage but short time frame (7-10 years)
  - Rely heavily on airborne gravity
- ◆ II. Low resolution movie
  - to track the temporal changes to the gravity field on a broad scale
  - a re-occurring survey with very coarse spatial coverage and a long time span.
- ◆ III. Terrestrial Partnership Surveys
  - to measure and/or track very localized gravity values of particular importance to the fine-scale local determination of heights

# Campaign III: Terrestrial Partnership Surveys

- ◆ “A ‘boots-on-the-ground’ re-check of each place where new airborne gravity surveys disagree with existing terrestrial gravity data”
- ◆ “In general such surveys are expected to rely heavily upon the partnerships NGS has formed, and will form, through a National Height Modernization program”
- ◆ “NGS will engage local partners in the surveys, including loaning equipment and providing training in the use of the equipment, and submittal of processed data to NGS.”
- ◆ “Potential for localized geoid slopes to be directly determined from field surveys of **co-located (space and time) leveling and GPS.**”



# From Astoria to Crater Lake....





# ....A Story of Bouys & Gals



# Unit of Gravity Measurements

- ◆ **Gal = 1 cm/sec<sup>2</sup>**
- ◆ **Named in honor of Galileo Galilei**



## “Average” Gravity Force on Earth’s Surface

- $32 \text{ ft/sec}^2$  is “average” force on Earth’s surface
- $= 9.8 \text{ meters/sec}^2$
- $= 980 \text{ centimeters/sec}^2$  (or **980 Gals**)
- $= 980,000 \text{ milliGals}$  (mGals)
- Typically, gravity observations are recorded in **milliGals**, a milliGal is about 1 millionth of the acceleration of gravity at the earth's surface.

# GRAVITY BASE STATION

LATITUDE 43°05.3'N (1)		STATION DESIGNATION  ALKALI LAKE	
LONGITUDE 119°57.5'W 119-58-20 (1)			
ELEVATION METERS		COUNTRY/STATE USA/Oregon	
REFERENCE CODE NUMBERS DOD 1277-0 1GB15639		ADOPTED GRAVITY VALUE  g = 980 033.59 mgals	
		ESTIMATED ACCURACY + 0.1 mgals	DATE MONTH/YEAR July 73

## DESCRIPTION AND/OR SKETCH

The observations were made at Alkali Lake Airport in Oregon.

The site is located at the north edge of the landing strip, in line with the center line of the road leading to the landing strip from HWY 395.

(1)



# Astoria

SC1055 CBN - This is a Cooperative Base Network Control Station.

SC1055 TIDAL BM - This is a Tidal Bench Mark.

SC1055 DESIGNATION - 943 9040 TIDAL 12

SC1055 STATE/COUNTY - OR/CLATSOP

SC1055 USGS QUAD - ASTORIA (1984)

SC1055 \*CURRENT SURVEY CONTROL

SC1055\* NAD 83(1998) - 46 12 26.45816(N) 123 46 01.25297(W) ADJUSTED

SC1055\* NAVD 88 - 5.495 (meters) 18.03 (feet) ADJUSTED

SC1055 ELLIP HEIGHT - -17.468 (meters) (03/21/00) GPS OBS

SC1055 GEOID HEIGHT - -22.94 (meters) GEOID03

SC1055 DYNAMIC HT - 5.496 (meters) 18.03 (feet) COMP

SC1055 MODELED GRAV - 980,713.5 (mgal) NAVD 88

SC1055 SUPERSEDED SURVEY CONTROL

SC1055 NAD 83(1991) - 46 12 26.45592(N) 123 46 01.25507(W) AD( ) B

SC1055 ELLIP H (10/13/99) -17.347 (m) GP( ) 3 1

SC1055 NAD 83(1991) - 46 12 26.46255(N) 123 46 01.21573(W) AD( ) 3

SC1055 NAD 27 - 46 12 27.08765(N) 123 45 56.70363(W) AD( ) 3

SC1055 NAVD 88 (10/13/99) 5.50 (m) 18.0 (f) LEVELING 3

SC1055 MARKER: DJ = TIDAL STATION DISK

SC1055 SETTING: 37 = SET IN A MASSIVE RETAINING WALL

SC1055 STAMPING: TIDAL NO 12 1962

SC1055 MARK LOGO: CGS

SC1055 MAGNETIC: N = NO MAGNETIC MATERIAL

SC1055 STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL

SC1055 SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR GPS

SC1055

SC1055 HISTORY - Date Condition Report By

SC1055 HISTORY - 1962 MONUMENTED CGS

SC1055 HISTORY - 20070325 GOOD USPSQD

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (CLS)

THE STATION IS LOCATED ABOUT 4.0 KM (2.50 MI) EAST OF ASTORIA, AT THE U.S. COAST GUARD BASE TONGUE POINT, IN TOP OF THE EAST END OF THE CONCRETE SEAWALL ON THE SOUTH SIDE OF THE PIER.

OWNERSHIP--U.S. COAST GUARD, TONGUE POINT FACILITY, ASTORIA, OR 97103-2099. CONTACT OFFICER

THE DAY PHONE 503-325-2378. TONGUE POINT JOB CORPS CENTER MANAGER IS GEORGE SABOL, PHONE 503

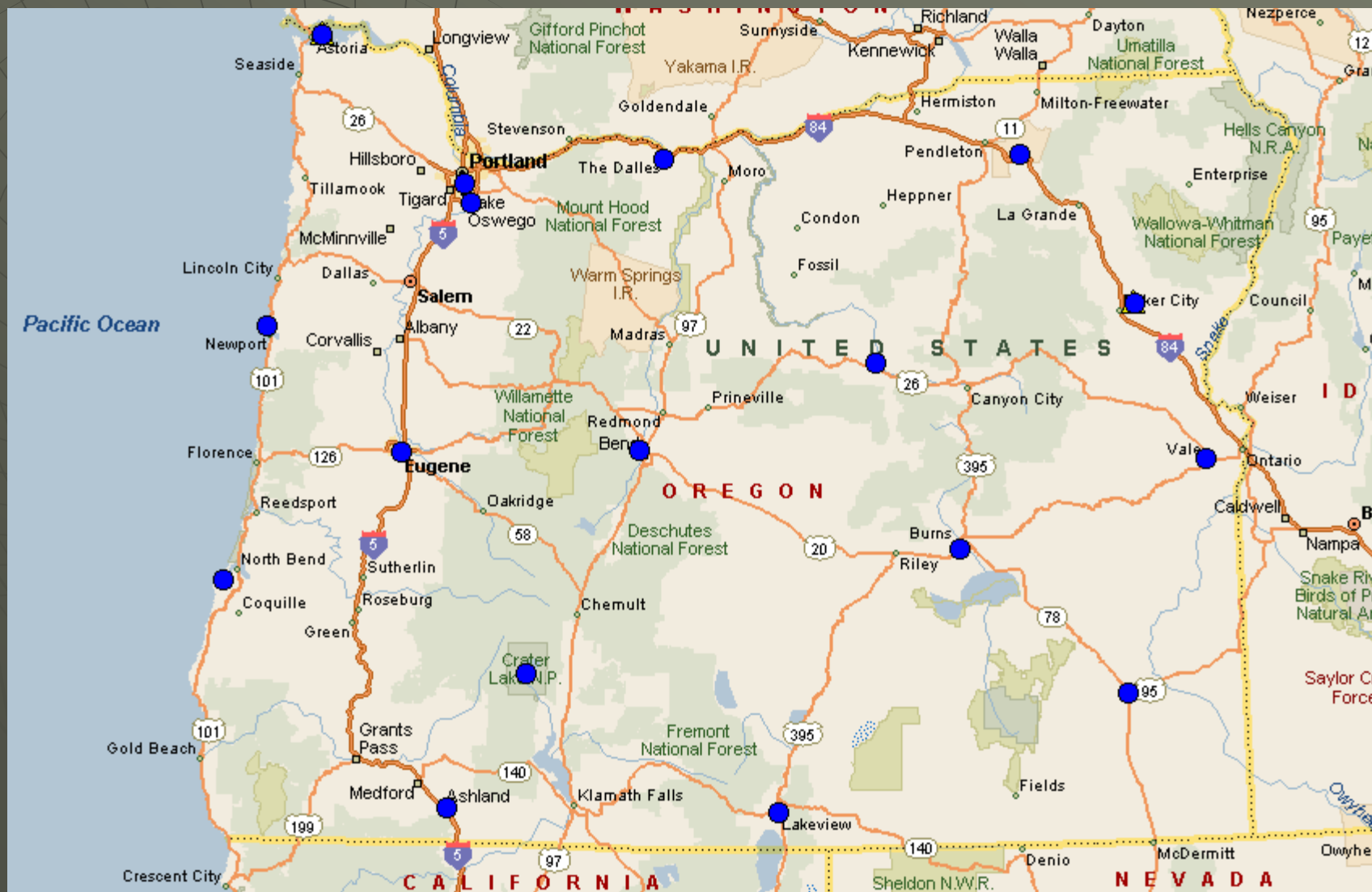
N  
# 7  
25-

old flag pole  
down, but distance  
from base of  
flag pole correct  
station is 2.6 m  
NW of NEW FLAG

# The Process

- ◆ Absolute gravity measured by Dan Winester, NGS
- ◆ Transfer absolute gravity reading to ground w/relative meter
- ◆ Transfer absolute ground to Excenter
- ◆ Search for Old Gravity Stations
- ◆ Run relative loops from Excenter to previously observed stations (double run)

# Absolute Sites



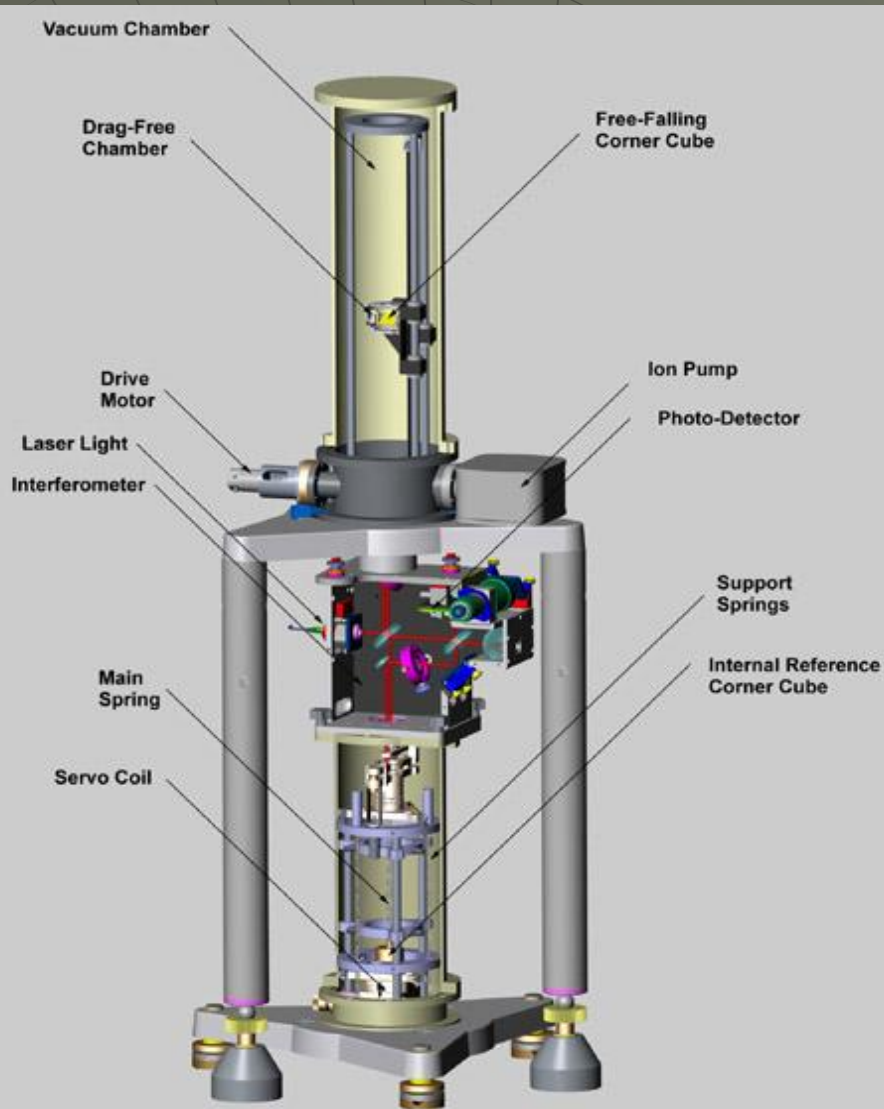


# Absolute Gravimeter





# Absolute Gravimeter



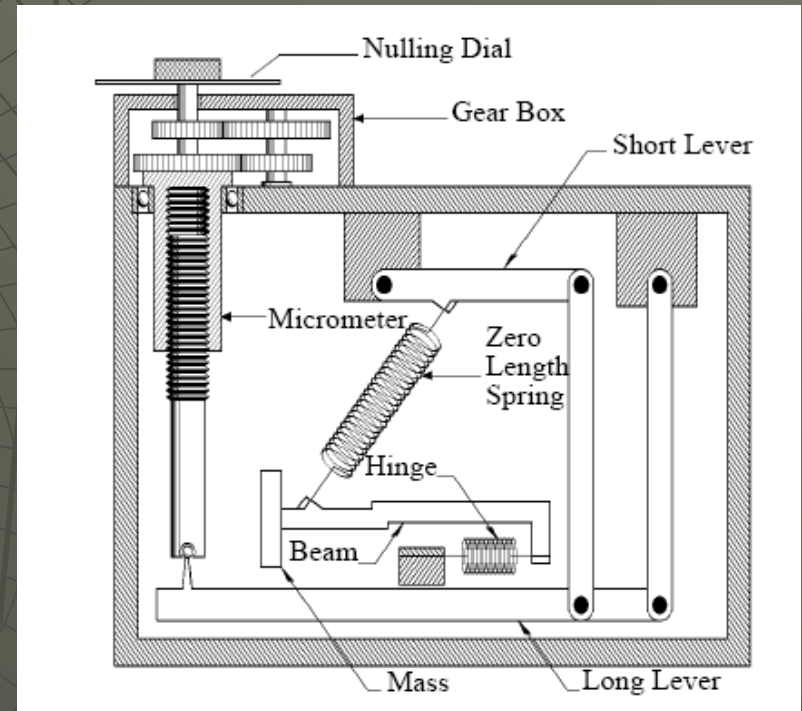
- ◆ Basically an accelerometer
- ◆ The descent of a free-falling object inside of the absolute gravimeter is monitored very accurately with an accurately timed laser interferometer
- ◆ Accuracy: 2 microGal (observed agreement between FG5 instruments)

# Transferring Gravity to the Ground

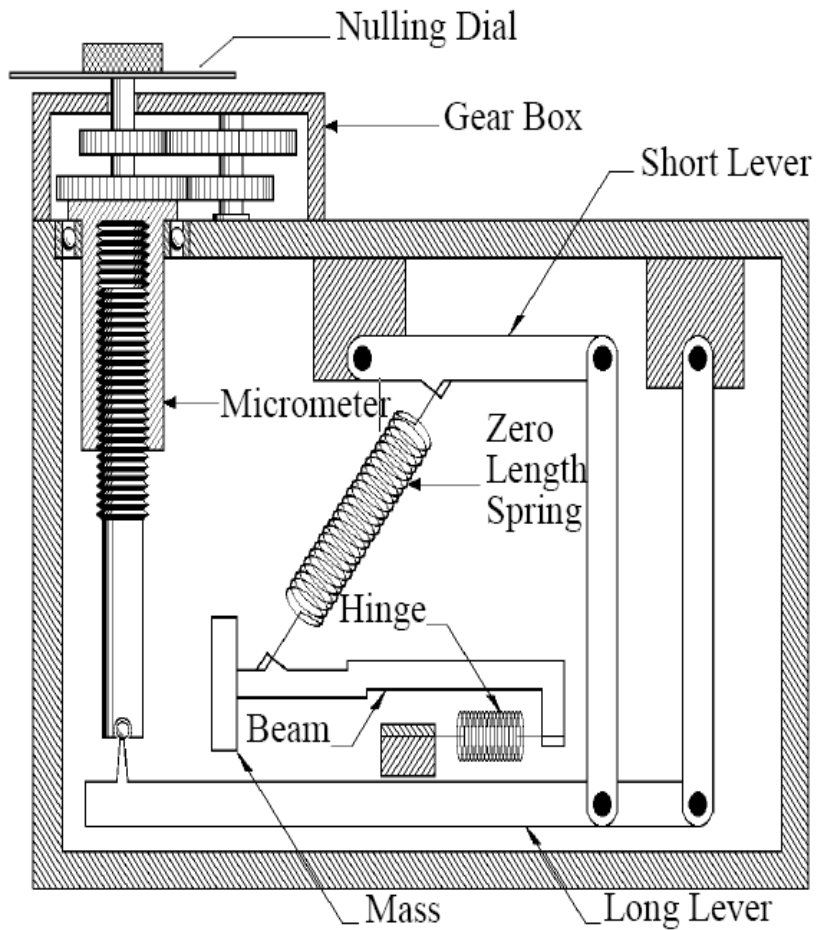




# Relative Gravimeter



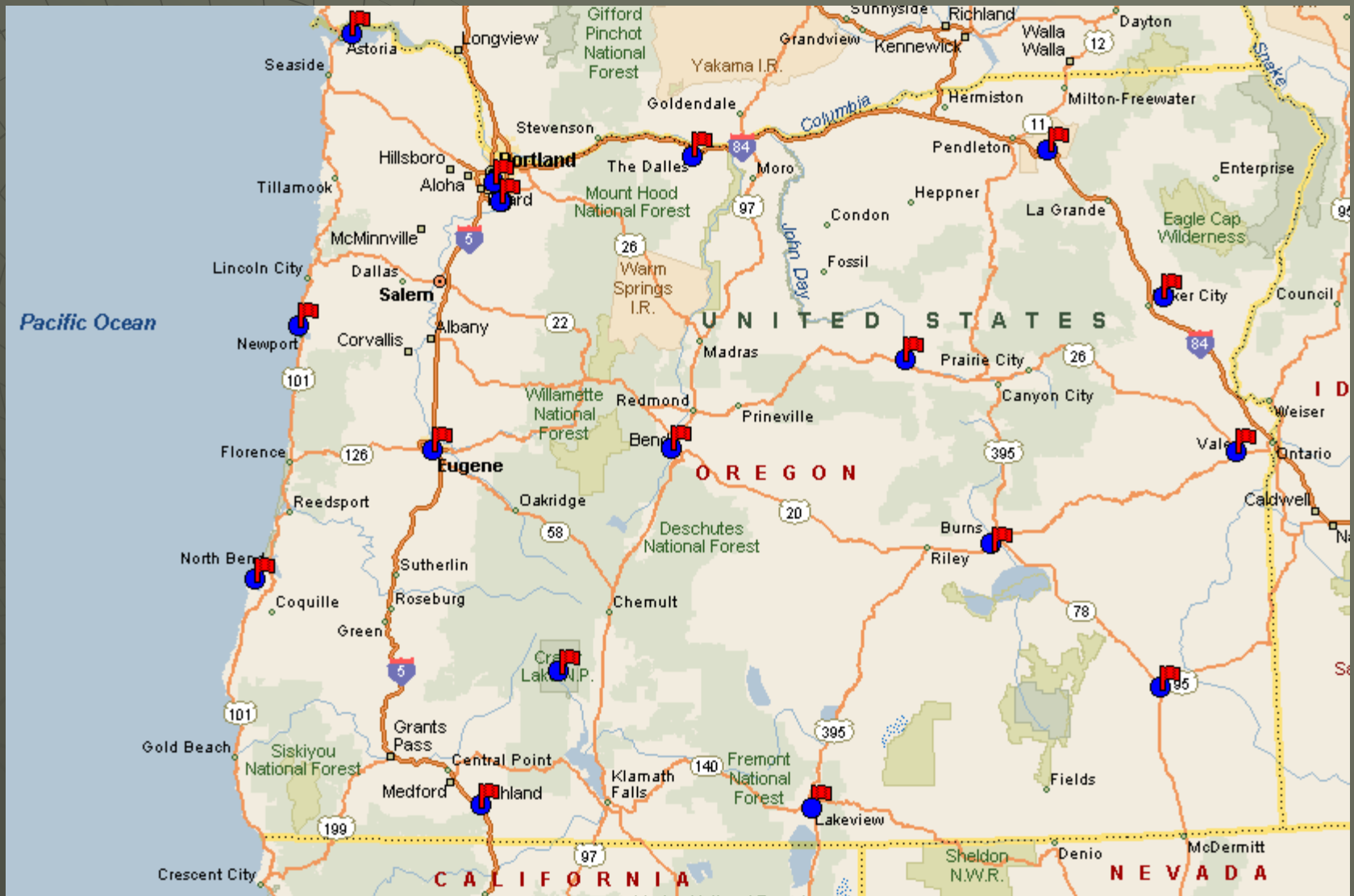
# Relative Gravimeter



- ◆ A spring used to counteract the force of gravity pulling on an object.
- ◆ The change in length of the spring may be calibrated to the force required to balance the gravitational pull on the object.



# Excenters

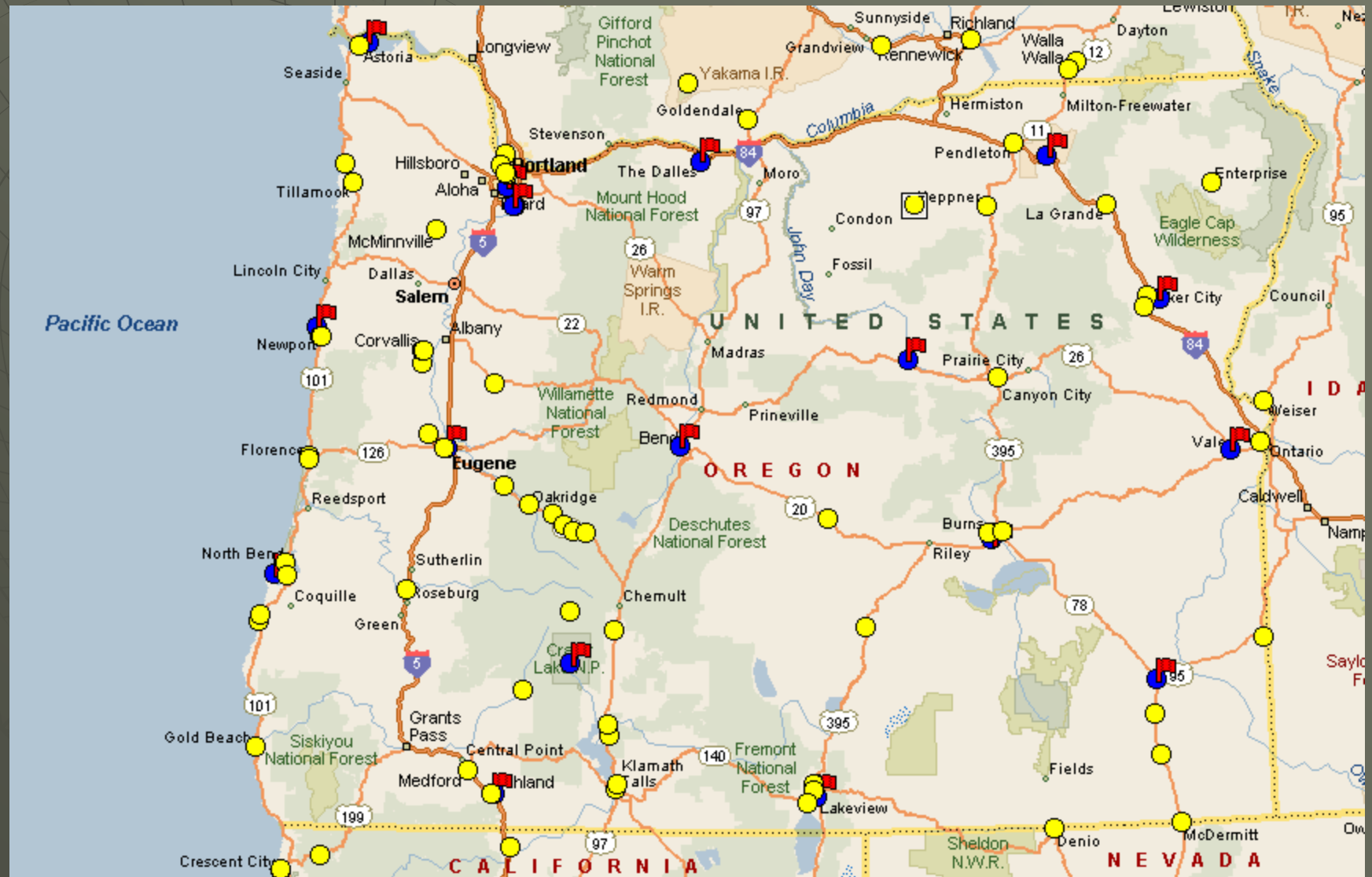


# Transferring Absolute to Excenter



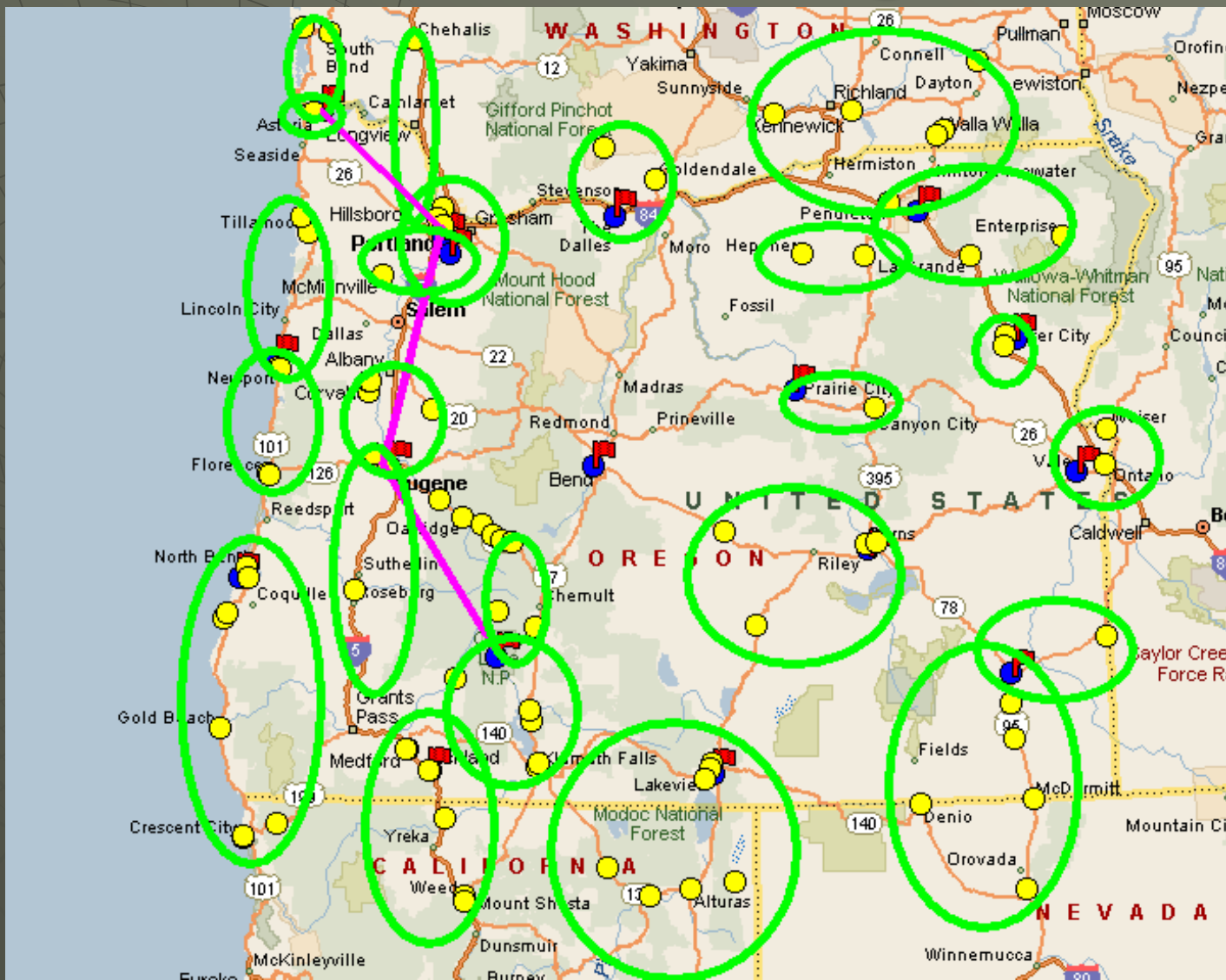
# Relative Sites

A map of Oregon showing various locations marked with yellow dots and red squares. The map includes major cities like Portland, Salem, Eugene, and Medford, as well as national forests and the Pacific Ocean. The map is titled "Relative Sites" in a large, stylized font at the top.





# 2007 Planning





# Searching for Gravity Stations

- ◆ Very Old Poorly Written Descriptions
- ◆ Many were not Monumented
- ◆ 100+ Stations to Measure
- ◆ Lots of Driving and Long Days
- ◆ Three Months to Complete the State

The elevation of the knife edge was 2,091 feet, based on city bench mark 2,089.7.  
The knife edge was 2 feet below the ground surrounding the building.

**U. S. 79, Boise, Idaho** (Ada County, H. D. King, 1910).—Station is located at Boise, in the new (1908) east wing of the high school at Tenth and Washington Streets, in the boys' dressing room in the south part of basement, directly beneath the Tenth Street entrance. The receiver was mounted on three bricks, each cemented to the concrete floor. *W.C.P. 8th room?*

The elevation of the knife edge was 2,697 feet, based on the elevation of the Oregon Short Line Railroad tracks in front of depot. The knife edge was about 10 feet below the surface of the ground surrounding the building.

**U. S. 80, Astoria, Oreg.** (Clatsop County, H. D. King, 1910).—Station is located at Astoria, at the southeast corner of the intersection of Lafayette and Chemarus Streets, in the Federal building (custom-house and post office), in the northwest part of the basement. The receiver was mounted on three bricks, each cemented to the concrete pier in a temporary room. *station destroyed*  
*this 1873 bldg. replaced*

The elevation of the knife edge was 8.4 feet above mean half tide. *at same location in 1923*  
The knife edge was 5 feet below the surface of the ground immediately surrounding the building.

**U. S. 81, Sisson, Calif.** (Siskiyou County, H. D. King, 1910).—Station is located at Berryvale, at the Sisson Tavern about 1 mile west and  $\frac{1}{4}$  mile south of Sisson railroad station, in the basement under the southwest corner of the main part of the building. The receiver was mounted on a concrete pier in a temporary room.

The elevation of the knife edge was 3,439 feet, based on the elevation of the railroad track at Sisson.

The knife edge was 1 foot above the surface of the ground on the west side of the building and 4 feet below the surface on the east side.

**U. S. 82, Rock Springs, Wyo.** (Sweetwater County, H. D. King, 1910).—Station is located at Rock Springs, at the city hall, in the basement, in a room just east of boiler room near the middle of the southeast side.

The receiver was mounted on a low concrete pier.

The elevation of the knife edge was 1,909.5 meters, based on bench mark N 3 (on the city hall).

The knife edge was 2 feet below the ground surrounding the building. *M 8 160*

**U. S. 83, Paxton, Nebr.** (Keith County, H. D. King, 1910).—Station is located at Paxton, at the Globe Hotel, in the southeast corner of the cellar under the storehouse at the rear. The receiver was mounted on three bricks, each cemented to the concrete floor.

The elevation of the knife edge was 3,056 feet, based on bench mark 3060 (U.S.G.S.). *MM 0208*

The knife edge was 1.5 feet below the surface of the ground surrounding the hotel.

**U. S. 84, Bureau of Standards, D. C.** (Washington, D. C., W. H. Burger, 1910).—Station is located at Washington, in room No. 16 in the Physical Laboratory or Main Building of the Bureau of Standards. The room is near the center of the basement and without windows, its only door being almost directly opposite the



# Excenter to Existing Gravity Stations around the state





ODOT put us up in some of the  
best places





# Precise Leveling in Oregon

- ◆ Preservation and replacement of Benchmarks in Oregon
- ◆ Run levels to stations of the Oregon Real-time GPS Network as part of Height Modernization program.
- ◆ “Potential for localized geoid slopes to be directly determined from field surveys of **co-located (space and time) leveling and GPS.**” NGS National Gravity Survey Plan

# Precise Leveling

- ◆ Acquired all equipment
  - First order Leica DNA-03 level
  - Invar rods
  - Invar 60 cm strip (for vertical Bm's)
  - Thermisters
  - Turtles
  - Turning Pins
- ◆ Acquired Training
  - NGS Precise Leveling Workshop
  - Curt Smith, NGS State Advisor tutorial provided on-project training

# Stanford Linear Accelerator Center

## Vertical Comparator for the Calibration of Leveling Equipment

- ◆ A fully automated vertical comparator for the calibration of digital levels and invar staffs
- ◆ Developed by the Metrology Department in cooperation with the Institute of Engineering Geodesy and Measurement Systems at the Graz University of Technology.
- ◆ The vertical comparator was built in 2003 in the SLAC Metrology laboratory







# Oregon Real-time GPS Network

[www.TheORGN.net](http://www.TheORGN.net)



# Administrator

- ◆ Oregon Department of Transportation
  - Geometronics Unit
- ◆ Program Manager: Ron Singh
- ◆ Technical Manager: Ken Bays
- ◆ ORGN Support: Randy Oberg

# Administrator Responsibilities

- ◆ Network quality control
- ◆ Network software operation
- ◆ Network software maintenance and upgrades
- ◆ User support

# Major Cooperators & Support

- ◆ NGS
- ◆ UNAVCO Plate Boundary Observatory
- ◆ Washington State Reference Network
  - Exchange of raw GPS data streams across the Columbia River.
- ◆ California and Idaho as their networks develops





# Partners

- ◆ Partners will provide sites, GPS equipment, and other major infrastructure to the network.
  - Government agencies
    - ◆ Inter-Governmental Agreements
  - Private entities
    - ◆ Public-Private Partnerships

# Some, but not all, of our Interested Partners

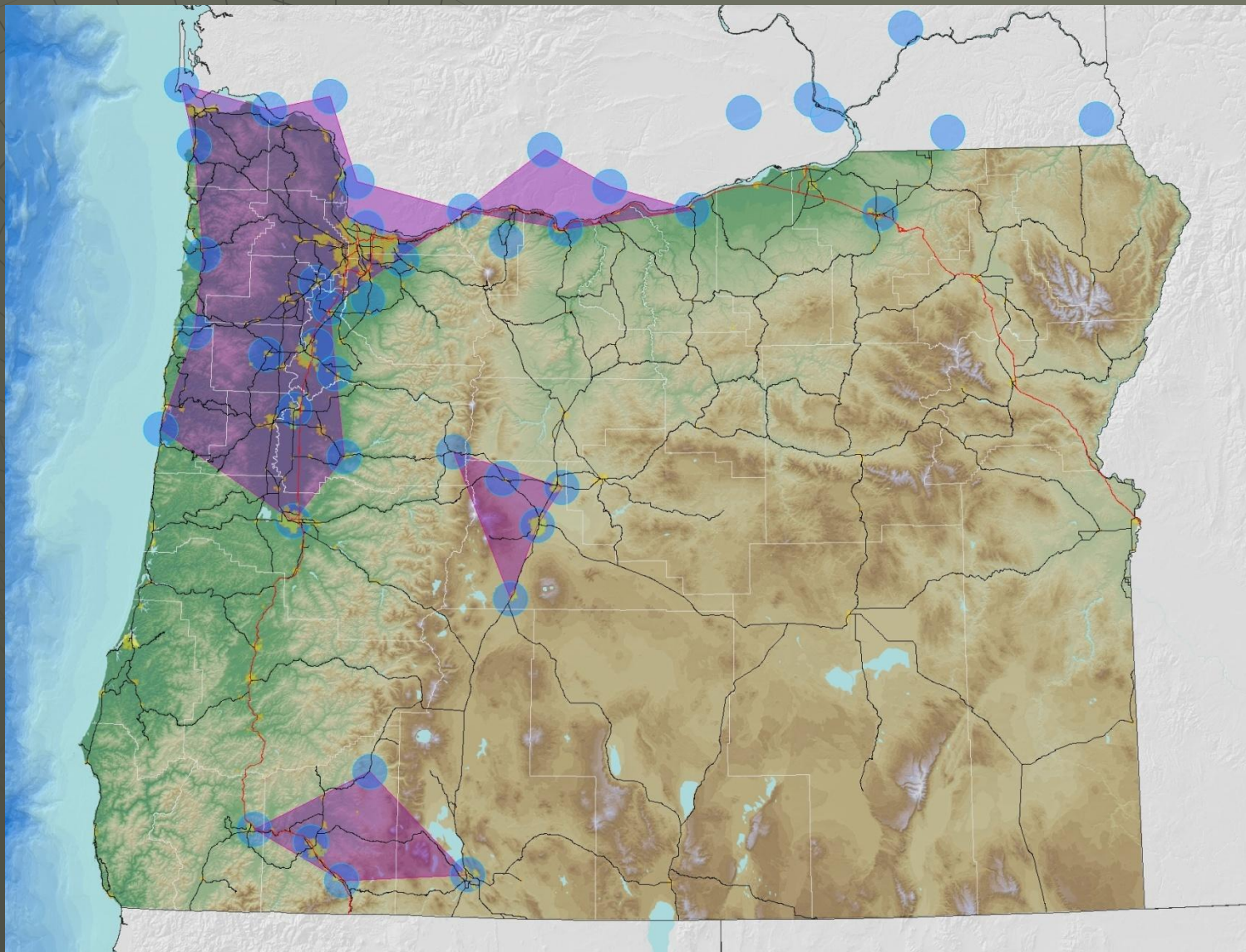
OBEC Consulting Engineers	Yamhill County
Polk County	City of Salem
Deschutes County	Clackamas County
EWEB	Marion County OR
City of Beaverton	Jackson County
City of Newberg	Lane County
Washington County	Tualatin Valley Water District
City of Springfield	Port of Portland
Curry County	Oregon State University
Washington DOT	City of Wilsonville
City of Bend	Clatsop County
Linn County	Douglas County
David Evans & Associates	Portland Water Bureau
Lincoln County	Benton County
Multnomah County	Oregon Parks and Recreation Department
Oregon Division of Aviation	

# Subscribers

- ◆ Anyone who is not a partner and wants access to RTK correctors data from the ORGN.
- ◆ Must have rover account set up
  - No direct fee at this time
  - Online rover account application at [www.TheORGN.net](http://www.TheORGN.net)
- ◆ May have minimal fee in future to cover operation, maintenance, and upgrades, but not to cover the build of the infrastructure of the network.

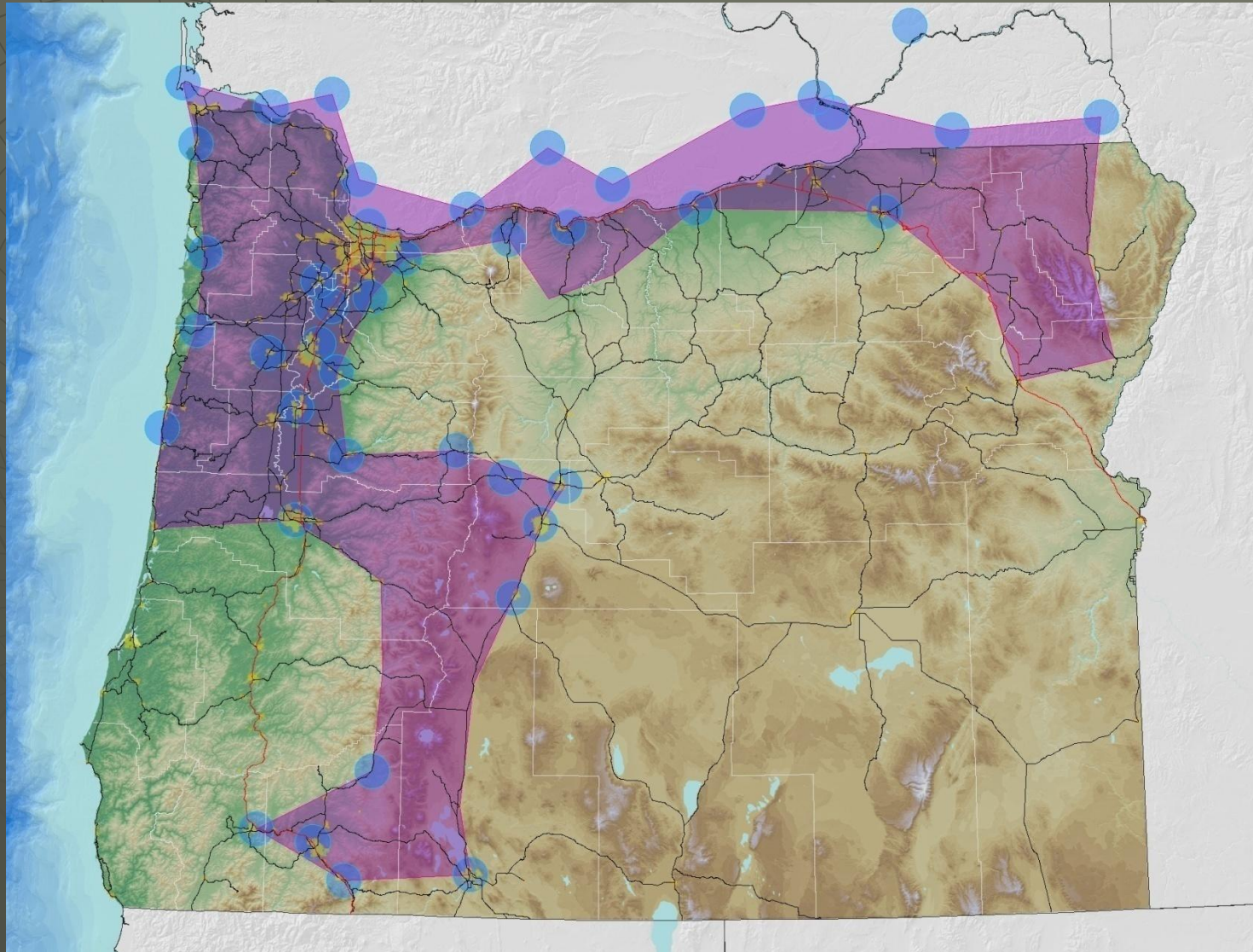


# September 2008



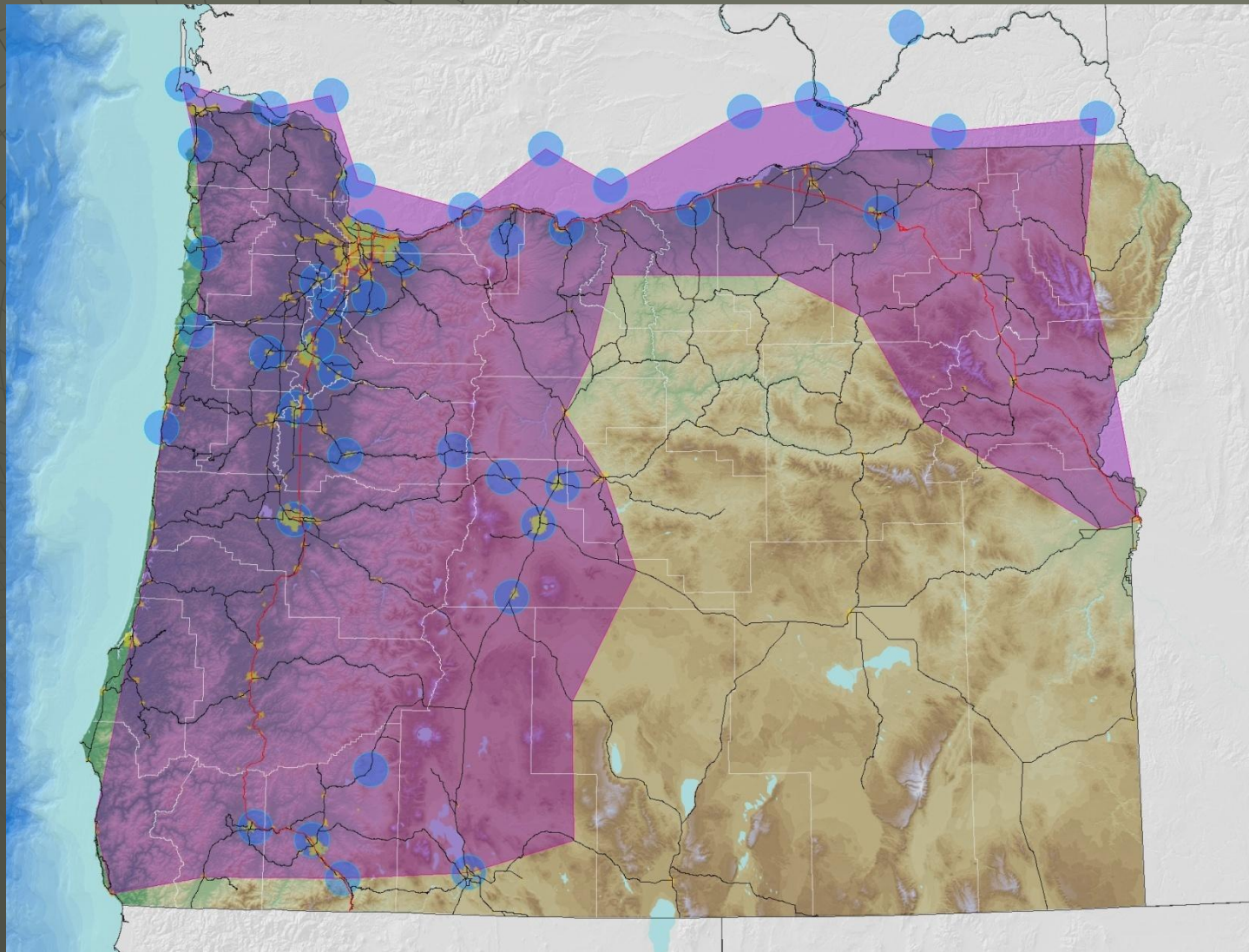


# December 2008





# July 2009





# Can I Trust the ORGN for Accurate GPS Positions?

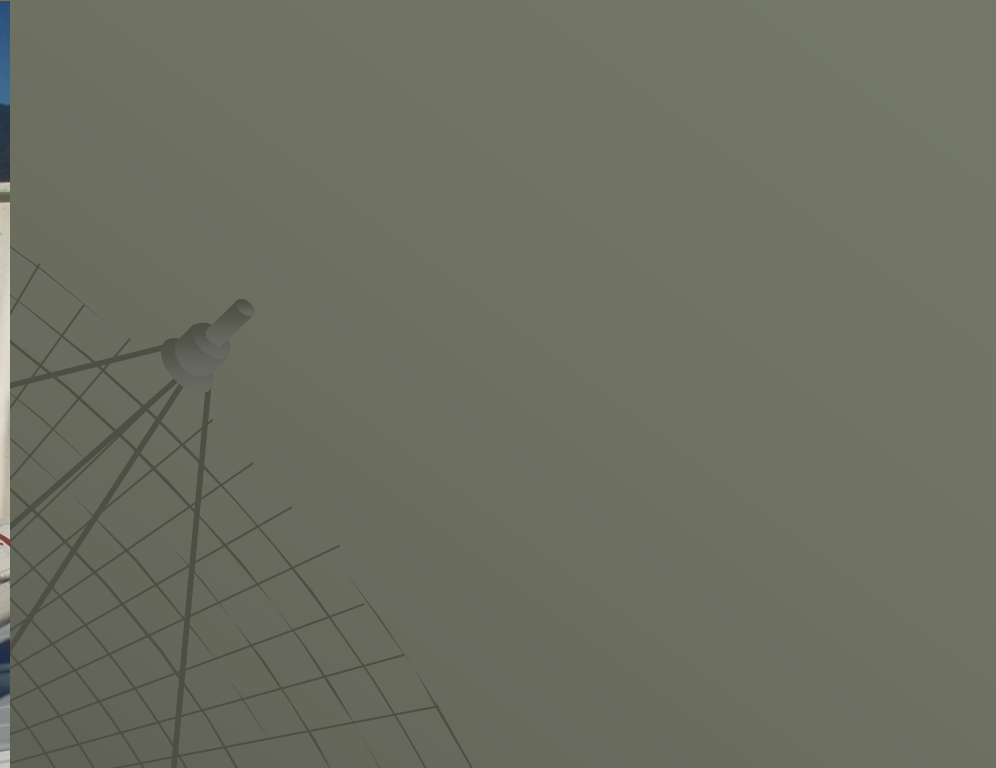
## Installation

- Pre-testing of Positions
- Extreme Care
- Sturdy Antenna Mounts
- ◆ Carefully Calculated Positions
- ◆ Constant Monitoring of Antenna Positions
- ◆ Precise Ephemeris used for Correctors

# Site Criteria Standards

- ◆ 60 Km Station Spacing
- ◆ Satellite visibility: clear view of sky
- ◆ No electromagnetic interference
- ◆ Pre-installation data quality sets: 3 days of GPS data
- ◆ Continuous power w/ backup
- ◆ Internet connectivity





### Quality Testing:

CycleSlips:	Pass	(Value 142 slips, Threshold 240 slips)
Multipath:	Pass	(Value 0.25m MP1 / 0.26m MP2, Threshold 1.5 m)
DataCompleteness:	Pass	(Value 99.4 %, Threshold 95.0 %)
EpochsWithData:	Pass	(Value 100.0 %, Threshold 99.0 %)
NavData:	Pass	
Format:	Pass	
RX Clock:	Pass	
Other:	Pass	





## Quality Testing:

CycleSlips:	Fail	(Value 420, Threshold 199)
Multipath:	Pass	(Value 0.21m MP1 / 0.26m MP2, Threshold 1.5 m)
DataCompleteness:	Pass	(Value 99.7 %, Threshold 95.0 %)
EpochsWithData:	Pass	(Value 100.0 %, Threshold 99.0 %)
NavData:	Pass	
Format:	Pass	
RX Clock:	Pass	
Other:	Pass	

# Solid Antenna Mounts



# ORGN Coordinates

## NAD83(CORS96)(Epoch2002)

	A	B	C	D	E	F	G	H	I	J	K
1	ORGN CORS NETWORK										
2	ASHL		LEIAT504 LEIS								
3	2006-07		N 42-10	W 122-40	(meters)	ERROR (reading-mean)					
4	Ephem	JulianDay	LAT	LONG	ELLIP. EL.	N(v)	E(v)	EL(v)	N(v2)	E(v2)	EL(v2)
5	P	318	50.47055	12.55213	609.16000	0.0000	0.0000	0.0052	0.00000	0.00000	0.00003
6	P	321	50.47062	12.55210	609.15300	0.0000	0.0000	-0.0018	0.00000	0.00000	0.00000
7	P	330	50.47058	12.55207	609.15600	0.0000	0.0000	0.0012	0.00000	0.00000	0.00000
8	P	334	50.47056	12.55201	609.16100	0.0000	-0.0001	0.0062	0.00000	0.00000	0.00004
9	P	335	50.47056	12.55202	609.15800	0.0000	-0.0001	0.0032	0.00000	0.00000	0.00001
10	P	340	50.47056	12.55206	609.15100	0.0000	0.0000	-0.0038	0.00000	0.00000	0.00001
11	P	344	50.47043	12.55208	609.15400	-0.0001	0.0000	-0.0008	0.00000	0.00000	0.00000
12	P	347	50.47058	12.55208	609.15300	0.0000	0.0000	-0.0018	0.00000	0.00000	0.00000
13	P	350	50.47057	12.55209	609.15500	0.0000	0.0000	0.0002	0.00000	0.00000	0.00000
14	P	359	50.47062	12.55217	609.15500	0.0000	0.0001	0.0002	0.00000	0.00000	0.00000
15	P	1	50.47066	12.55208	609.14700	0.0001	0.0000	-0.0078	0.00000	0.00000	0.00006
16											
17	11-day	mean	50.47057	12.55208	609.15482	USE			sum v2	0.0000	0.0000
18	4-day		50.47065	12.55213	609.15				/N-1	0.0000	0.0000
19			-0.00008	-0.00005	0.00482				√ Northing	√ Easting	√ Elevation
20											
21									Sigma =	0.0001	0.0000
22									3 Sigma	0.0002	0.0001
23											
24											
25											
26											
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30											
31											
32											
33											
34											

**Direction and Distance - [inverses]**

General

From Point Id: ☒ ASHL 11 day

To Point Id: ☐ ASHL 4 day 2006

Geodetic Azimuth: 337° 37' 26.0"

Ellipsoidal Distance: 0.0030 m

Ellipsoidal Height Diff.: -0.0048 m

Slope Distance: 0.0057 m



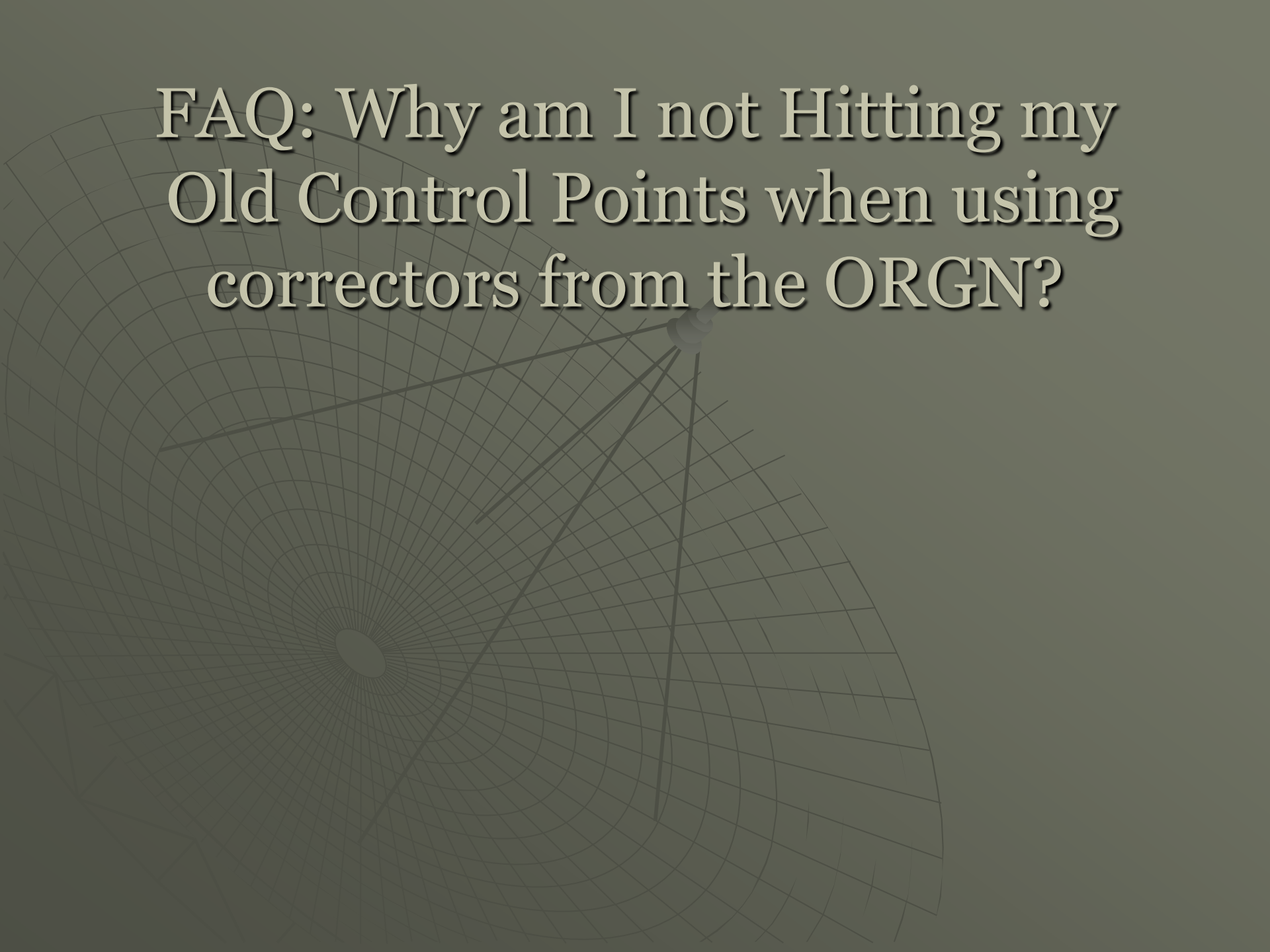
# Comparison of Ephemerides

- ◆ Broadcast (predicted) Ephemeris
  - Sent from GPS satellites as part of the navigation message when you are collecting data.
- ◆ Precises Ephemerides
  - Ultra-rapid Ephemeris
    - ◆ ORGN Spider software grabs Ultra Rapid Ephemeris every few hours and applies to RT correctors transmitted by the ORGN.
  - Rapid Ephemeris
  - Final Precise Ephemeris

**IGS Product Table [GPS Broadcast values included for comparison]**

		Accuracy	Latency	Updates	Sample Interval
GPS Satellite Ephemerides/ Satellite & Station Clocks					
Broadcast	orbits	~160 cm	real time	--	daily
	Sat. clocks	~7 ns			
Ultra-Rapid (predicted half)	orbits	~10 cm	real time	four times daily	15 min
	Sat. clocks	~5 ns			
Ultra-Rapid (observed half)	orbits	<5 cm	3 hours	four times daily	15 min
	Sat. clocks	~0.2 ns			
Rapid	orbits	<5 cm	17 hours	daily	15 min
	Sat. & Stn. clocks	0.1 ns			5 min
Final	orbits	<5 cm	~13 days	weekly	15 min
	Sat. & Stn. clocks	<0.1 ns			5 min

FAQ: Why am I not Hitting my  
Old Control Points when using  
correctors from the ORGN?



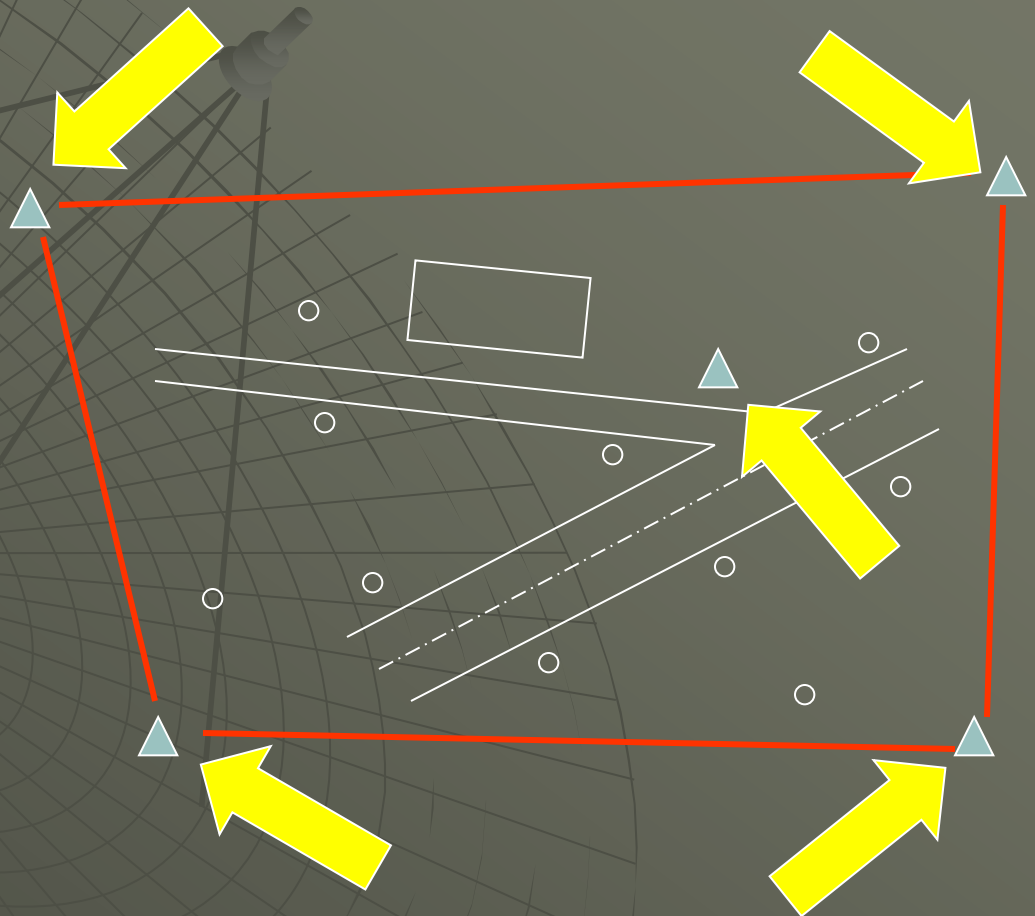


# Outreach/Education

- OSU Workshop: Using the ORGN: Feb 2008
- PLSO Conference: Getting Started with the ORGN: March 2008
- ODOT Surveyors Conference: April 2008

# Site Calibration

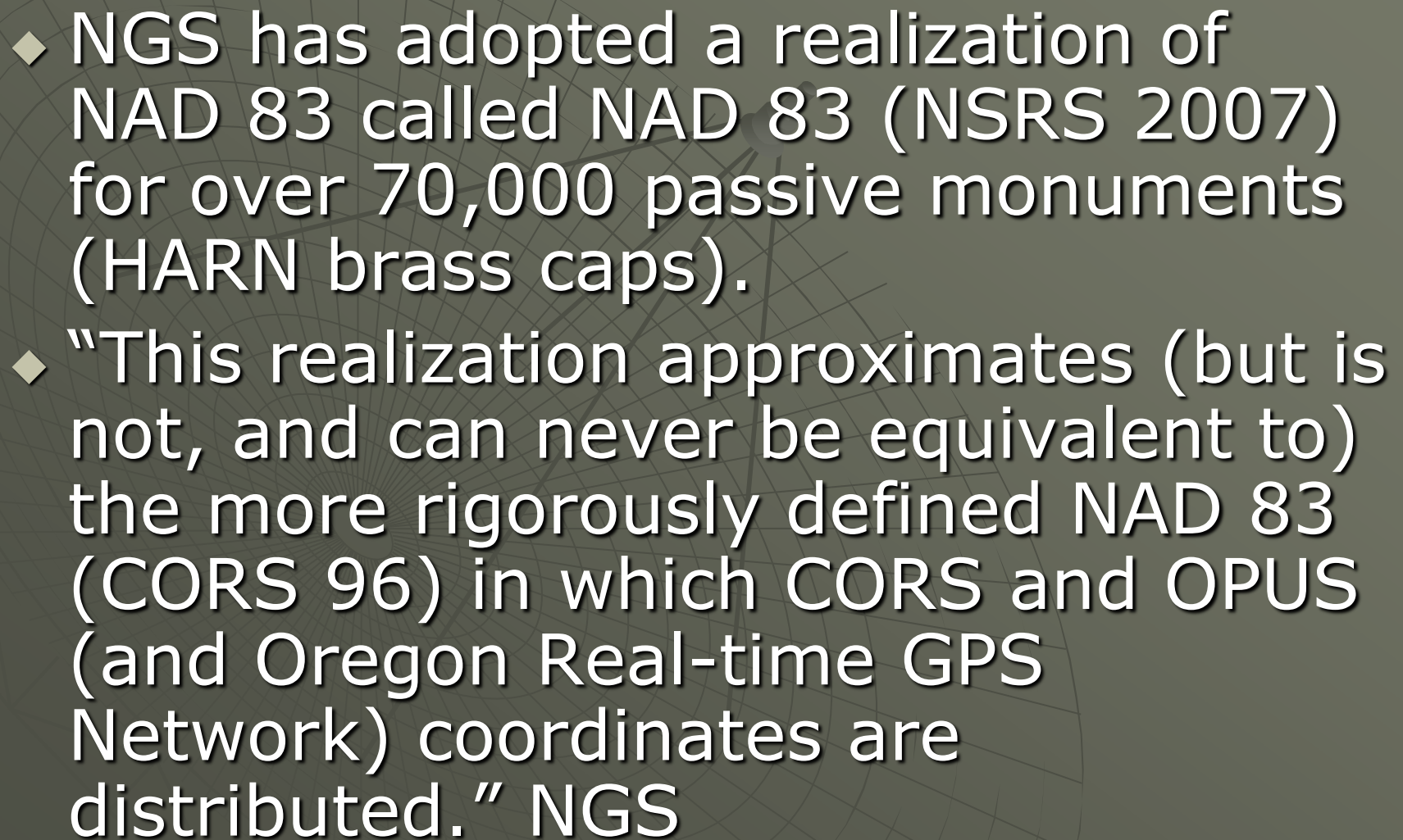
- ◆ Calibrate to points that surround the project that have coordinates known in the local system.
- ◆ Occupy calibration points with GPS while receiving real-time correctors from the ORGN, then calibrate to the local system.



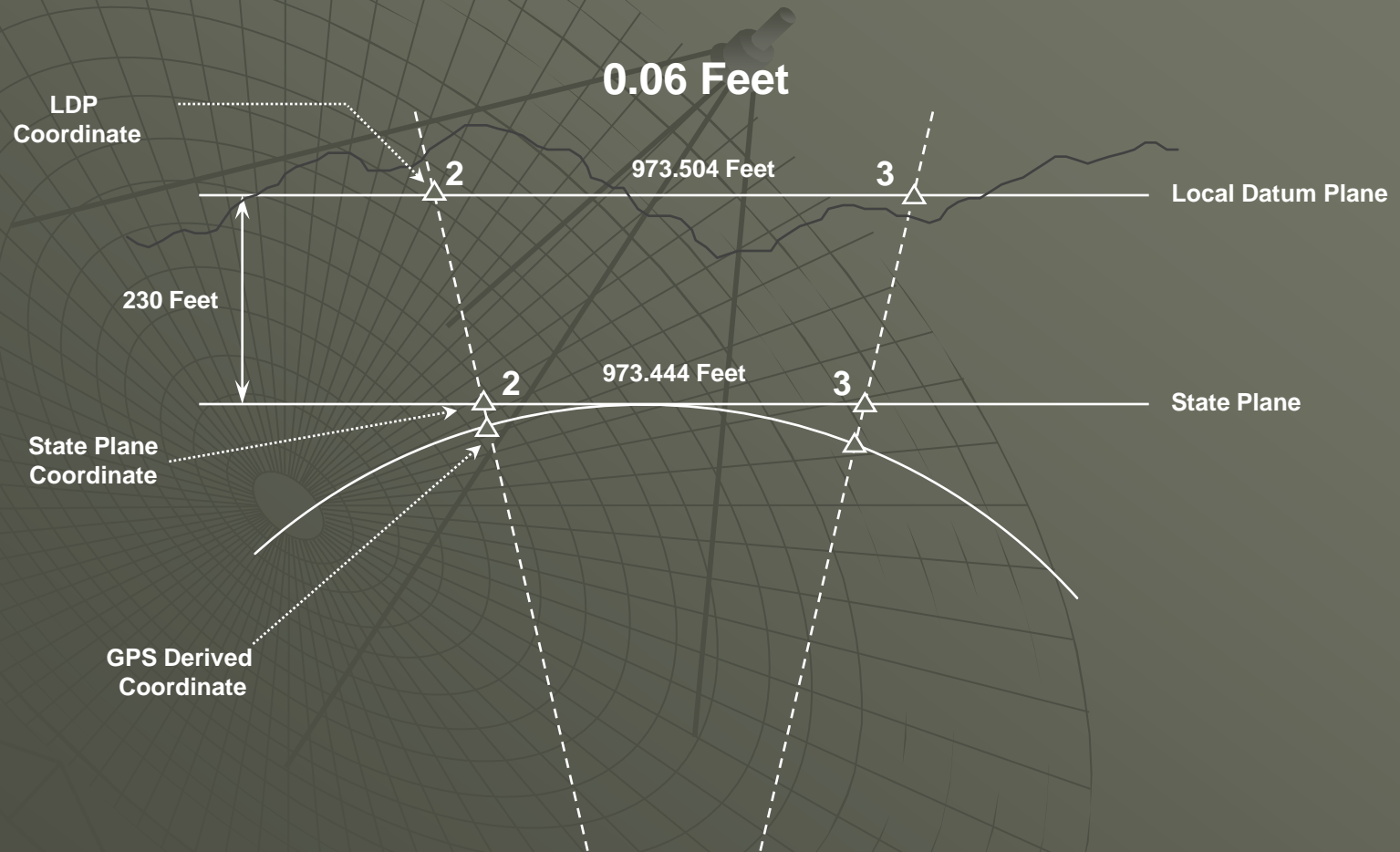


FAQ: Why am I not hitting  
published HARN positions when I  
use correctors from the ORGN?

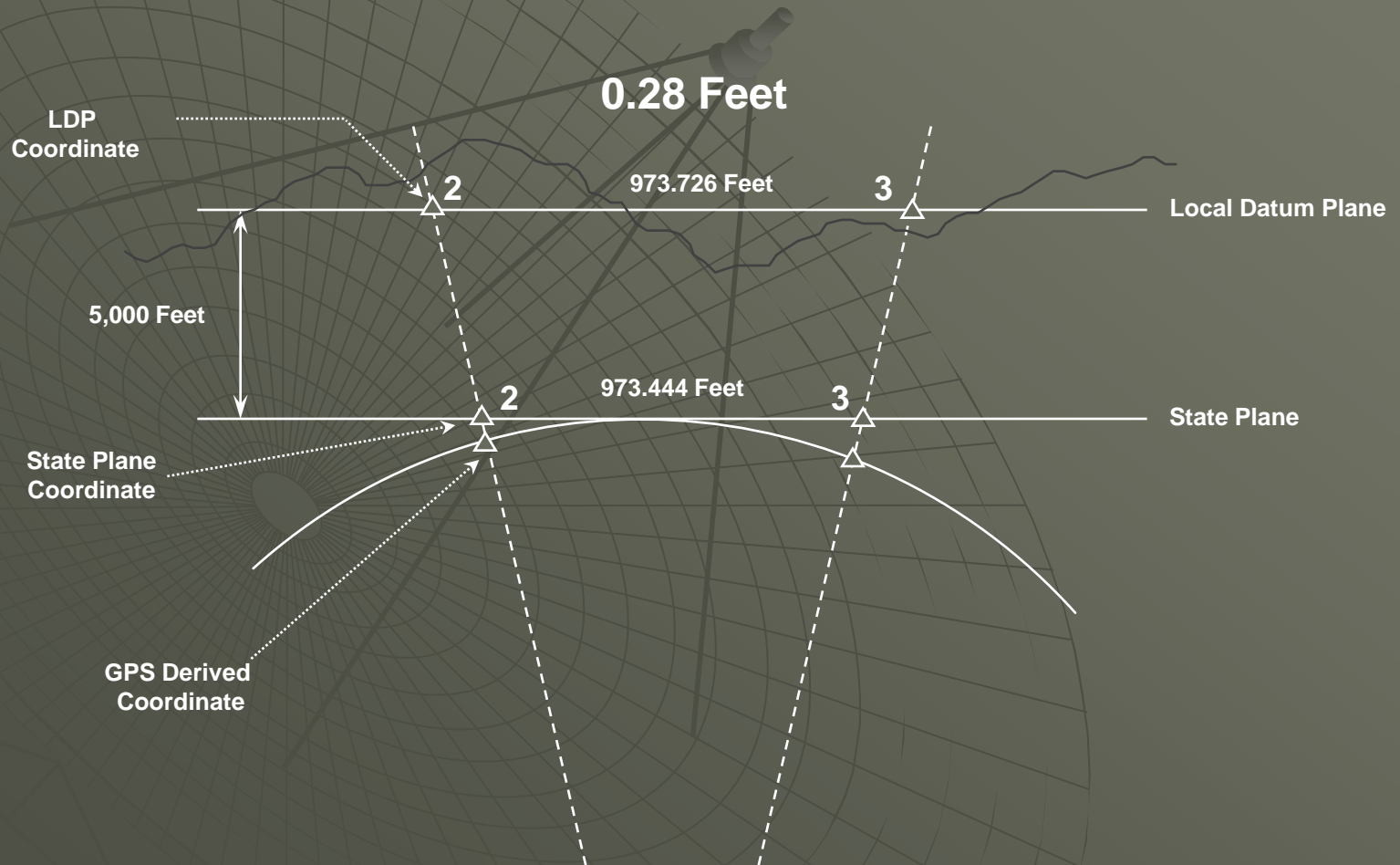


- 
- ◆ NGS has adopted a realization of NAD 83 called NAD 83 (NSRS 2007) for over 70,000 passive monuments (HARN brass caps).
  - ◆ “This realization approximates (but is not, and can never be equivalent to) the more rigorously defined NAD 83 (CORS 96) in which CORS and OPUS (and Oregon Real-time GPS Network) coordinates are distributed.” NGS

# Distortion Due to Elevation



# Distortion Due to Elevation





# Low Distortion Projections Workshop

November 4, 2008

Albany, Oregon

Co-sponsors:

- Oregon GPS Users Group
- Oregon DOT Geometronics Unit
- More info: [www.ogug.net](http://www.ogug.net)

- 
- ◆ Ken Bays
  - ◆ [kenneth.bays@odot.state.or.us](mailto:kenneth.bays@odot.state.or.us)
  - ◆ 503-986-3543
  - ◆ [www.TheORGN.net](http://www.TheORGN.net)

# NAD 83( CORS 96) and NAD 83(NSRS2007)

- ◆ NGS has adopted a realization of NAD 83 called NAD 83(NSRS2007) for the distribution of coordinates of the High Accuracy Reference Networks (HARN) ~70,000 passive geodetic control monuments.
- ◆ This realization *approximates* (but is not, and can never be, equivalent to) the more rigorously defined NAD 83 (CORS 96) realization in which Continuously Operating Reference Station (CORS) coordinates are and NGS Online Positioning User Service (OPUS) coordinates are distributed.
- ◆ NAD 83(NSRS2007) was created by adjusting GPS data collected during various campaign-style geodetic surveys performed between the mid-1980's and 2005.
- ◆ For this adjustment, NAD 83 (CORS 96) positional coordinates for ~700 CORS were held fixed (predominantly at the 2002.0 epoch. for the stable north American plate, but 2007.0 in Alaska and western CONUS) to obtain consistent positional coordinates for the ~70,000 passive marks, as described by Vorhauer [2007]. Derived NAD 83(NSRS2007) positional coordinates should be consistent with corresponding NAD 83( CORS 96) positional coordinates to within the accuracy of the GPS data used in the adjustment and the accuracy of the corrections applied to these data for systematic errors, such as refraction.
- ◆ In particular, there were no corrections made to the observations for vertical crustal motion when converting from the epoch of the GPS survey into the epoch of the adjustment, while the NAD 83 ( CORS 96) coordinates do reflect motion in all three directions at CORS sites. For this reason alone, there can never be total equivalency between NAD 83(NSRS2007) and NAD 83( CORS 96).
- ◆ Note: NGS has not computed NAD 83(NSRS2007) velocities for any of the ~70,000 passive marks involved in this adjustment. Also, the positional coordinates of a passive mark will make reference to an "epoch date". Epoch dates are the date for which the positional coordinates were adjusted, and are therefore considered "valid" (within the tolerance of not applying vertical crustal motion). Because a mark's positional coordinates will change due to the dynamic nature of the earth's crust, the coordinate of a mark on epochs different than the listed "epoch date" can only be accurately known if a 3-dimensional velocity has been computed and applied to that mark.